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A COMPACT UNIVERSAL POWER SUPPLY FOR LASER DIODES

ARMSTRONG LABORATORY

Daniel X. Hammer, First Leiutenant, USAF

Optical Radiation Division
Brooks Air Force Base, Texas

Gary D. Noojin

The Analytical Sciences Corporation (TASC)
750 East Mulberry, Suite 302
San Antonio, Texas

Floyd Messick, Technical Sergeant, USAF
William Robinson
Jessica L. Josephson, Airman, USAF

Operations and Support Directorate
Brooks Air Force Base, Texas

ARMSTRONG LABORATORY (AFMC)
OCCUPATIONAL ENVIRONMENTAL HEALTH DIRECTORATE
Optical Radiation Division
8111 18th St
Brooks Air Force Base, TX 78235-5215

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DANIEL X. HAMMER, 1Lt, USAF
Research Electrical Engineer
Optical Engineering Branch

ROBERT M. CARTLEDGE, Lt Col, USAF, BSC
Chief, Optical Radiation Division

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A Compact Universal Power Supply for Laser Diodes

INTRODUCTION

A compact universal power supply for laser diodes was designed and built. The power source will supply current for laser diodes with forward operating current up to approximately 350 mA. The power supply has a feedback stage, a slow start circuit, ac transient suppression, and digital optical power meter. The power supply is based upon a Toshiba design[1], with modifications in the feedback loop to provide utility for a wide range of laser diodes. The power supply was built into a compact unit and tested on: a Toshiba TOLD9200 visible laser diode[2] with optical power of 3 milliwatts (mW) at an operating current of approximately 75 mA; an Oki OL308A-75 high power infrared laser diode[3] with optical power of 80 mW at an operating current of approximately 220 mA; and a Sharp near infrared laser diode with optical power of 3 mW at an operating current of approximately 57 mA.

The appendix contains the operating procedure for the laser diode power supply and the specification sheets for the Toshiba TOLD9200 and Oki OL308A-75 laser diodes tested in this report. The specification sheets for the Sharp laser diode were not available.

BACKGROUND

Laser diodes have become increasingly important in the technological community for their advantages over other types of lasers. Laser diodes are smaller and more efficient for lower electrical power requirements, and have a relatively high response to input currents. Various applications in use today include laser printers, compact disc players, bar code readers, and laser eye surgery.

Laser diodes, like light emitting diodes (LEDs), are composed of a semiconductor p-n junction. However, unlike LEDs, laser diodes emit stimulated, coherent light from a double-hetero structure. This structure is composed of an active layer sandwiched between the n-clad and p-clad layers. Higher efficiencies are achieved with narrow current channels. The two main types of laser diode configurations, gain-guided and index-guided, are shown in Figure 1. The index-guided laser provides a more stable horizontal transverse mode than the gain-guided laser.

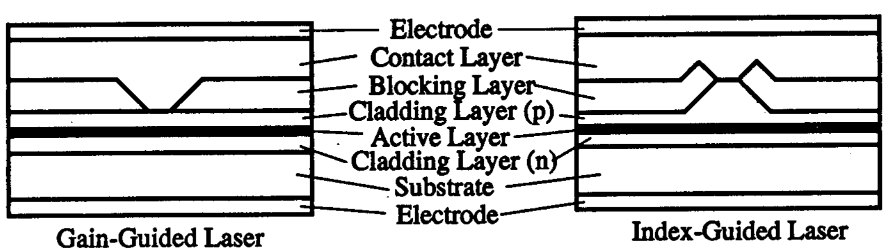

Figure 1: Laser Diode Configurations

Laser diode packages are typically composed of a laser diode and a photo diode. The laser diode emits light from the forward reflecting face. The photo diode monitors the light emitted from the laser diode's rear reflecting face and outputs a current proportional to the optical power. The photo diode uses feedback to modulate the output power. Laser diodes have a current threshold for stimulated light emission. Below this level they produce spontaneously emitted light. Corresponding to this current threshold is an optical power threshold. A typical forward current-optical power curve is shown in Figure 2.

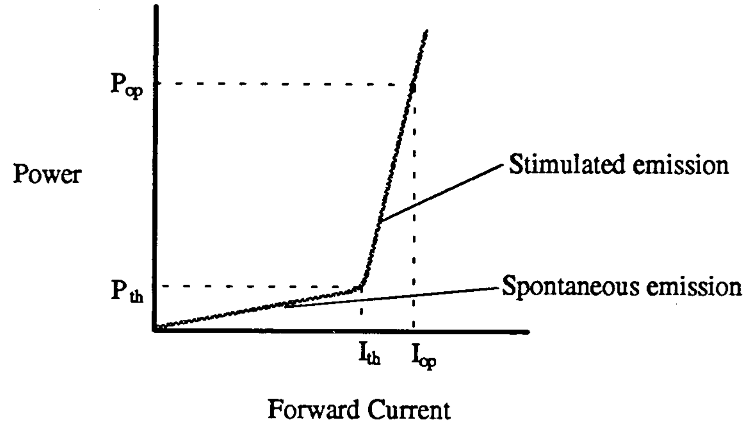

Figure 2: Typical Current-Power Curve

Along with the threshold current and the optical power, the specification sheets will list ranges for the operation current, lasing wavelength, monitor current, and beam divergence. The beam divergence is typically quite large (a full angle divergence of approximately 40° is common) in the perpendicular transverse direction due to the narrow active layer. The wavelength range will be determined by the number of longitudinal modes generating oscillations and the gain bandwidth of the semiconductor. Laser diodes can be single mode or multimode.[4]

POWER SUPPLY DESIGN

Prices of laser diode power supplies on the market today range from approximately $400.00 to $4,000.00. These power supplies have a variety of useful features, such as integrated thermoelectric cooler, microprocessor control, analog interface card, external analog modulation input and multiple current ranges, important to some users of laser diodes. However, often all that may be needed is a simple supply that controls the optical power and protects the laser diode from damage. The power supply design presented in the next paragraph is such a design. All of the components cost less than $200.00 and the unit could be built and tested in 6-8 hours. The design is based upon a design from Toshiba with a few modifications. The circuit diagram for the power supply is shown in Figure 3.

Monitor Current, Feedback Circuit, and Operating Current Control

The power supply operates as follows. The photodiode outputs a monitor current proportional to the optical power of the laser diode. The unity gain buffer outputs a voltage depending on the monitor current and the resistance set by the 50K potentiometer (R_{v1}), 3.9K resistor (R_{f1}), and 10K trim potentiometer (R_{f2}) in series. The voltage output of the second op-amp is the difference between 5.1 V (set by the 1N4733 Zener diode) and 100 times the voltage from the unity gain buffer. This large gain is required because the monitor current from the photodiode is very small. The voltage across the 470 Ω resistors will drive the current source (2N2222 transistor) which increases or decreases the current to the laser diode and, hence, the optical power. By adjusting R_{v1}, the optical power of the laser diode is controlled, and feedback is accomplished with the photodiode.

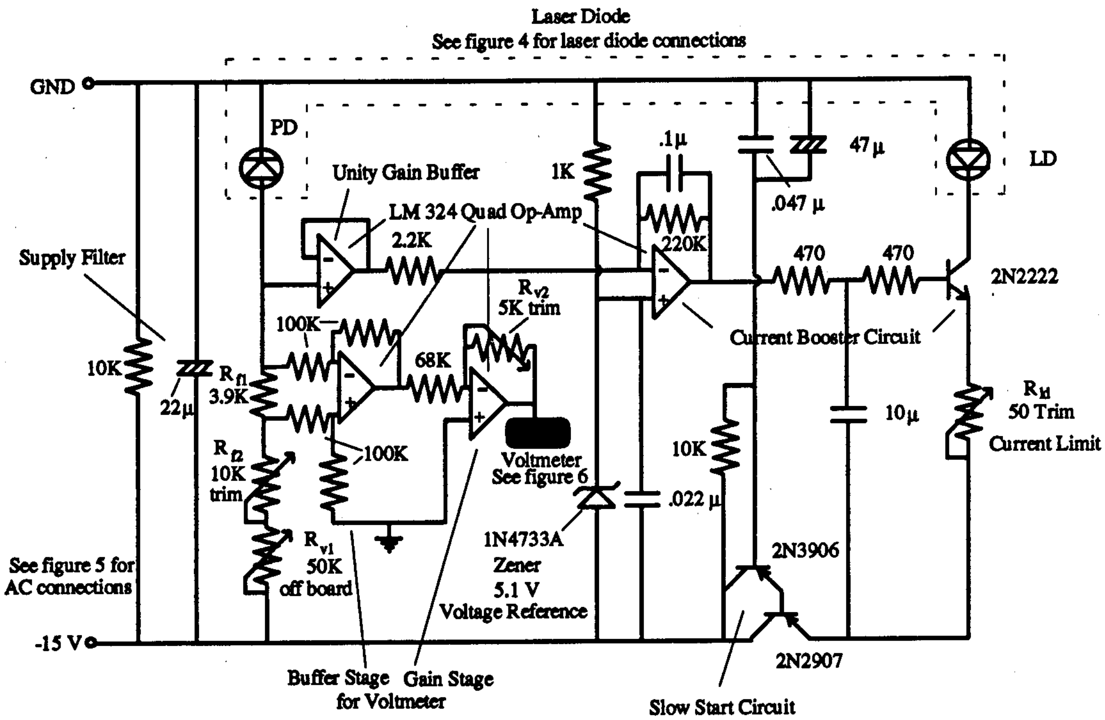

Figure 3: Circuit Diagram for Power Supply

The values for the components were chosen so that they could be adjusted for different laser diodes by someone familiar with the operation of the power supply. However, the casual user has control of only one potentiometer for optical power adjustment. The design protects expensive laser diodes from damage by careless users. For example, R_{f1} and R_{f2} are on the circuit board and can be accessed only by removing the cover of the power supply. R_{v1}, the resistance that controls the optical power, is accessible on the front panel.

R_{v1}, R_{f1}, and R_{f2} were chosen as follows. The minimum resistance across the line into the positive input of the unity gain buffer corresponds to the maximum monitor current allowed by the laser diode. This resistance is found from the formula,

$$R_f = \frac{5.1}{I_{m(max)}}$$

where $R_f = R_{f1} + R_{f2}$. The minimum resistance value selected for R_{f1} was 3.9K. That value was chosen from a review of the specification sheets for a number of different laser diodes. R_{f2} is set to the minimum resistance for different laser diodes and R_{v1} controls the optical power required. For example, the maximum monitor current for the TOLD9200 laser diode is 0.7 mA. Hence, R_f must be set at 7.3K, R_{f1} set at 3.9K and R_{f2} set at 3.4K. For the TOLD9201, the maximum monitor current is 1.4 mA. With R_{f1} set at 3.6K and R_{f2} set at 0.0K, the maximum monitor current will never be reached. R_{f1} (3.9K) is needed to display the optical power, as explained in the AC connections section. R_{v1} was chosen so that the optical power has the widest range for a large variety of laser diodes. This allows the user maximum controllability over the optical power, from just below the lasing threshold, when R_{v1} is maximum, to just below maximum monitor current, when R_{v1} is minimum. The user may then attenuate excess light by other external means, such as neutral density filters. Therefore, the choice of resistors makes the power supply adaptable with little modification for most laser diodes on the market, with the exception of the very high power (>.5 W) laser diodes.

The forward operating current of the laser diode is controlled by the 50 Ω potentiometer (R_{ld}). This resistance was computed from the theoretical voltage drop across the laser diode (between 2.2 V and 3.0 V) and from testing performed to find the optimum resistance at this node. The resistance value was chosen conservatively for the Oki OL308A-75 high power laser diode. Care should be taken to set this resistance value high enough so the forward current does not exceed its maximum ratings.

Each of the potentiometers must be carefully readjusted when changing laser diodes according to the directions in the operating instructions in the appendix of this report.

Slow Start Circuit and Voltage Surge Protection

The slow start circuit consists of two transistors in a Darlington configuration in series with two parallel capacitors. This design will delay the flow of current into the laser diode. The surge voltage protection consists of two parts, an RC filter on the board and an LC filter connected to the laser diode. These filters will protect against stray voltage spikes or transients that may occur on power lines. Figure 4 shows the LC connections to the laser diode.

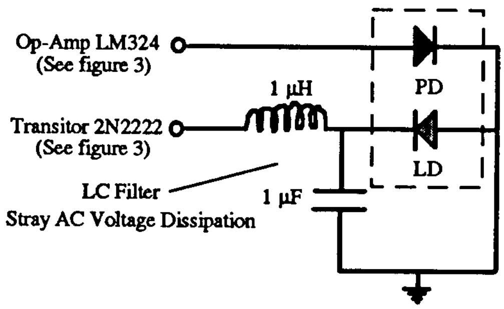

Figure 4: Laser Diode Connections

AC Connections

The AC connections are shown in Figure 5. This circuit provides +15 V, -15 V, and +5 V required to operate the power supply. The 120/40 VAC Center Tap Transformer and full wave rectifier supply the +5 V and +15 V regulators with +20 V and the -15 V regulator with -20 V both at .5 Amps. The 1000 μF storage capacitors serve as a supply filter. The 0.33 μF capacitors are RF bypass filters. They filter high frequency noise which may send the circuit into oscillation. The 0.22 μF capacitors are not required for stability, but provide better transient response.

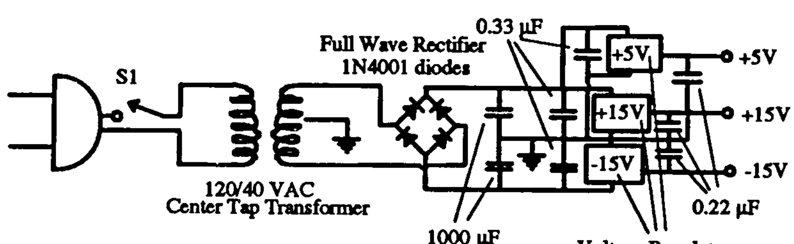

Figure 5: Connections to 120VAC

Optical Power Measurement

The approximate optical power of the laser diode is measured and displayed on a digital LED on the front panel of the power supply. The optical power is measured by calibrating the measurement stage of the circuit with the monitor current, which is proportional to the optical power of the laser diode. The calibration is done by a two-stage circuit whose gain is set by the 5K trim potentiometer (R_{v2}). The low values of the monitor current make this gain stage necessary. The two-stage circuit samples the voltage drop across R_{f1}. The first buffer stage has a gain of 1 and is used to separate the second stage from the rest of the power supply circuit. The second stage has a gain of -0.075 and lower (inversion and attenuation of signal). Again, this gain was chosen to be variable to accommodate the wide variety of laser diodes on the market. The voltmeter display is a Datel DMS-30PC LED Digital Panel Meter and has a readout from 0 mV to 200 mV. This display will correspond to a power output from 0 - 200 mW. The display has two ranges, corresponding to relatively high power laser diodes (> 10 mW) and low power laser diodes (<10 mW). The difference between the two ranges is merely the decimal point selected. For low power laser diodes, the gain stage cannot attenuate the voltage necessary (the gain does not reach a theoretical 0) to output less than 10 mW. However, the stage will work to attenuate the voltage down to 10 mV so by moving the decimal point, we can read out 1 mW. The display does not work below approximately 1 mW for the low power range and 10 mW for the high power range. The 5 K trim potentiometer must be readjusted every time new ranges are selected, or when using different diodes. If even more range is needed for different applications, different display panels can be used. The connnections to the digital LED display are shown in Figure 6. The display test switch is a push button switch to verify that the LED display is functioning, and the range switch sets the required range.

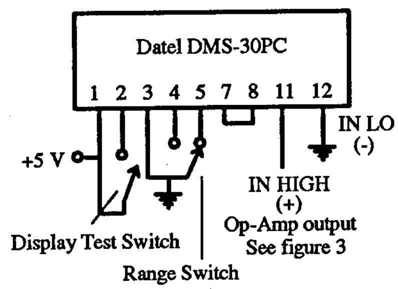

Figure 6: Connections to digital panel meter

Heat sink design

All laser diodes must be heat sinked to dissipate the large amounts of heat generated in the active region. Any design may be used as long as it dissipates the heat fast enough. Our heat sinks were designed according to the Toshiba application notes as follows[1]. The simplified formula describing the temperature relationship of a heat sink is

$$\theta_f \equiv \frac{T_c - T_a}{I_{op} \times V_{op}} - (\theta_s + \theta_c)$$

where θ_f = thermal resistance of heat sink
θ_s = thermal resistance of insulator sheet
θ_c = contact thermal resistance
T_c = case temperature
T_a = ambient temperature.

From the specification sheet in the appendix, we substitute $T_c = 50^{\circ}C$, $T_a = 25^{\circ}C$, $\theta_c = 8^{\circ}C/W$, $\theta_s = 0$ (no insulator sheet), $I_{op} = 288$ mA, and $V_{op} = 5$ V into the above equation resulting in $\theta_f = 16^{\circ}C/W$. From the figure in reference 1, we get a surface area of approximately 18 cm^2 for 2 mm thick aluminum to dissipate the required amount of heat. We chose an aluminum anondized heat sink 90 x 105 x 8 mm with large 75 mm fins to remain well above the area required for sufficient heat dissipation. The heat sink is shown in Figure 8. There are components on the market that incorporate the heat sink with the collimating or focusing optics[5].

DISCUSSION

As previously stated the resistor settings can be varied according to different laser diode specifications. Therefore, three different laser diodes were tested to prove that the design will work on a wide variety of laser diodes. Table 1 lists the resistor settings for each of the laser diodes tested and the optical power attained by each compared to the specifications listed by the manufacturers' specifications (see the appendix). The table lists the range that $R_{v1}+R_{f2}$ must be adjusted for laser operation, R_{v2}, the optical power measured, and the optical power specified.

Table 1. Laser diodes settings

Laser Diode Type	Sharp LT020MCO	Toshiba TOLD 9200	Oki OL308A-75		
Serial Number	--	7685	1004	1006	1010
$R_{v1}+R_{f2}$ (laser oper range)	15-30	16-40	0-30	0-30	0-30
R_{v2}	1.88	2.20	0.89	0.87	1.03
Max Optical Power (measured)	3.2	3.1	71.8	73.8	86.0
Max Optical Power (specified)	3	3	75	75	75

Figure 7 plots the voltage displayed on the LED digital display vs. the optical power as measured by a calibrated Scientech 365 power meter for each of the three different types of laser diodes. The optical power displayed for the Oki was in the high power range and the optical power displayed for the Sharp and Toshiba laser diodes was in the low power range. The variable resistance, R_{v2}, was adjusted for each of the laser diodes for optimum performance. The curves for the optical power displayed and the optical power measured have a very close fit throughout the operating region of the laser diodes.

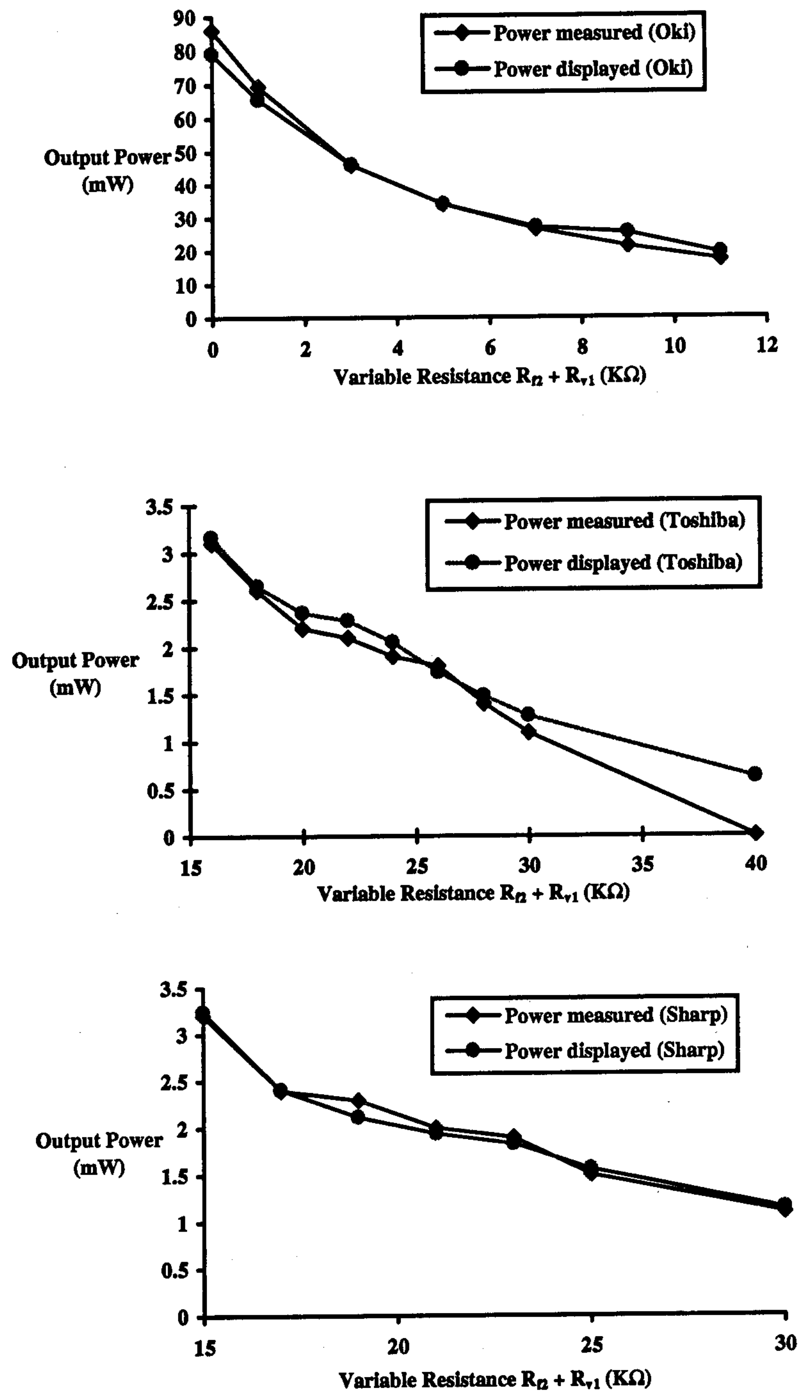

Figure 7: Optical power measured vs. optical power displayed

CONCLUSION

The results show that the laser diode power supply controls the three laser diodes tested to within 10% across their entire range of operation. This power supply will control all laser diodes that require less than 300 mA operation current. The power supply design is not meant to replace the much more sophisticated power supplies that may be purchased from many manufacturers. However, for a fraction of the cost and relative ease of fabrication, a reliable power supply may be built from the design. Three more complex power supply designs are listed in the references[6,7,8]. Figure 8 shows the laser diode power supply connected to an Oki OL308A-75 with heat sink.

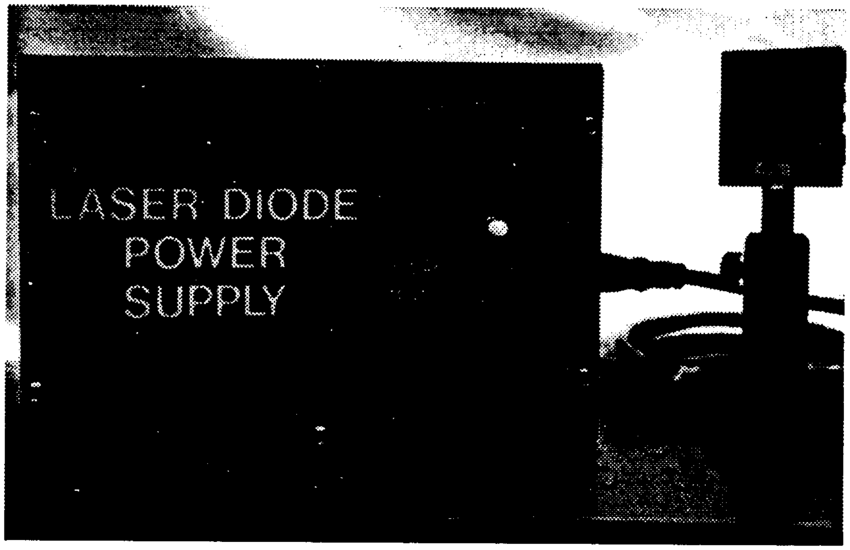

Figure 8: Laser Diode Power Supply with Oki Laser Diode

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1. R. Iannini, "Build a Semiconductor Laser System," *Radio Electronics*, Nov. 1990, pp. 34-40 and correspondence with J. Motodate, Toshiba America Electronic Components, Inc.

2. Toshiba Optoelectronic Semiconductor Laser Diode Product Guide, pp. 10-11.

3. Oki Optoelectronic Devices Data Sheet

4. Toshiba Laser Diode Question and Answer Manual

5. Melles-Griot Optics Guide 5, Sec. 20-23, among others

6. M. S. Cafferty, E. D. Thompson, "Stable current supply with protection circuits for a lead-salt laser diode," *Review of Scientific Instruments*, Vol. 60, No. 9, p. 8296, 1989

7. E. A. Lebedev, V. I. Markov, A. G. Chesnokov, "Power supply circuit for semiconductor light-emitting diodes and laser diodes, utilizing the intrinsic radiation of the source to stabilize the power," *Soviet Journal of Optical Technology*, Vol. 55, No. 2, p. 58, 1988

8. I. B. Grushev, A. V. Pavlenko, "Multifunction regulated power supply for continuous semiconductor laser," *Instruments and Experimental Techniques*, Vol. 33, No. 4, Pt. 2, p. 1084, 1989

APPENDIX

Operating Procedure for Laser Diode Power Supply

Refer to Figure 3 in the technical report for location of the potentiometers.

1. Check the specification sheets for the laser diode to be used. Note the monitor current, I_m, the forward operating current of the laser diode, I_f(LD), and the optical power output. If the values for the laser diode are not known, proceed to step two. A knowledge of these values will expedite the calibration procedure but are not necessary for operation of the laser diode.

2. Set up the laser diode to test the monitor current and the optical power. This procedure will require the diode to be heat sinked, and the use of a power meter. Place the diode so that all of its light will fall on the face of the power meter detector (this placement may require the diode to be very close to the detector face - within 2 or 3 mm). A review of the parallel and perpendicular output angles of the light in the specification sheets will give some idea as to the divergence of the beam.

3. Switch the laser diode to high power (> 10 mW) or low power (< 10 mW) on the front panel.

4. Set all potentiometers to maximum.

5. Adjust R_{f2} according to the following:

$$R_f = \frac{5.1}{I_{m(\max)}}$$

where R_f = 3.9K + R_{f2} and I_m is the monitor current. For example, if the monitor current specified is .7 mA, then R_{f2} must be set to 3.4K. If the monitor current specified exceeds 1.3, set R_{f2} to minimum. If the monitor current is not known, set it to maximum.

6. Adjust R_{ld} according to the following:

$$R_{ld} = \frac{3.0}{I_{f(\max)}}$$

where I_f is the forward operating current of the laser diode. For example, if the forward operating current specified is 100 mA, set R_{ld} to 30 Ω. R_{ld} may need to be adjusted a large amount. This adjustment is easily accomplished without damaging the laser diode providing the optical power is monitored and does not exceed its maximum ratings. If the forward operating current is not known, set it to maximum.

7. Slowly adjust R_{v1} until there is light out of the laser diode. If the forward operating current and the monitor current were set to maximum in steps 6 and 7, then they will need to be adjusted for optimum performance. This adjustment will be a trial and error process unless these values can be obtained.

8. Measure the optical power with a power meter. Adjust R_{v1} to get a full range of power values. If the optical power exceeds the maximum ratings, increase R_{f2} until it is at the maximum power rating when R_{v1} is minimum. Adjust R_{v2} until the output display matches the power meter within 10% at several different power values.

9. The power supply is now set to the particular laser diode you are using. Adjustment of the laser diode is accomplished with R_{v1} only. If a new laser diode is installed, repeat this entire procedure.

10. To test the display panel, depress the switch on the front panel for no more than 5 seconds.

11. For further information, consult the power supply technical report.

Technical Data

TOLD9200(s)

MAXIMUM RATINGS ($T_C = 25°C$)

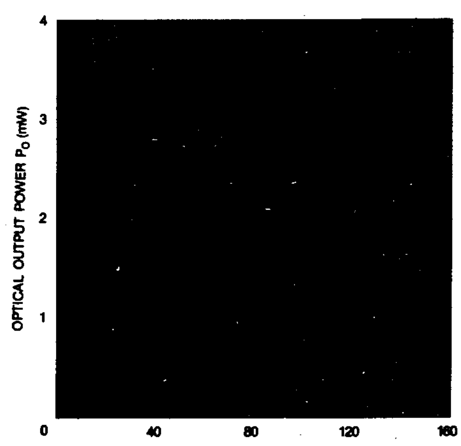
CHARACTERISTIC	SYMBOL	RATING	UNIT
Optical Output Power	P_O	3	mW
LD Reverse Voltage	$V_{R(LD)}$	2	V
PD Reverse Voltage	$V_{R(PD)}$	30	V
Operation Case Temperature	T_C	−10~50	°C
Storage Temperature	T_{stg}	−40~85	°C

OPTICAL-ELECTRICAL CHARACTERISTICS ($T_C = 25°C$)

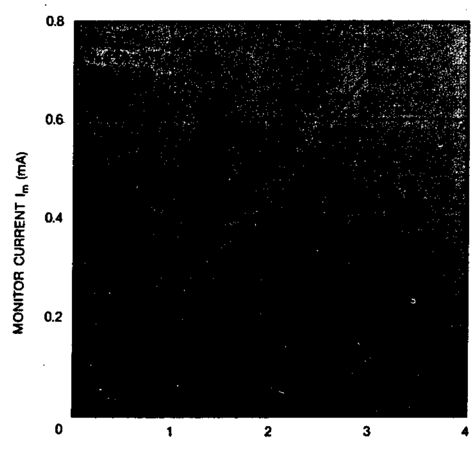
CHARACTERISTIC	SYMBOL	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Threshold Current	I_{th}	CW operation	—	70	90	mA
Operation Current	I_{op}	$P_O = 2mW$	—	75	100	mA
Operation Voltage	V_{op}	$P_O = 2mW$	—	2.3	3.0	V
Lasing Wavelength	λ_p	$P_O = 2mW$	660	670	680	nm
Beam Divergence	$\theta_{//}$	$P_O = 2mW$	4	7	12	deg.
	$\theta_{\perp}$	$P_O = 2mW$	27	34	40	
Monitor Current	I_m	$P_O = 2mW$	0.15	0.45	0.70	mA
PD Dark Current	$I_{D(PD)}$	$V_{rev} = 5V$	—	—	100	nA
PD Total Capacitance	$C_{T(PD)}$	$V_{rev} = 5V$, f=1MHz	—	—	20	pF

Examples of Typical Characteristics

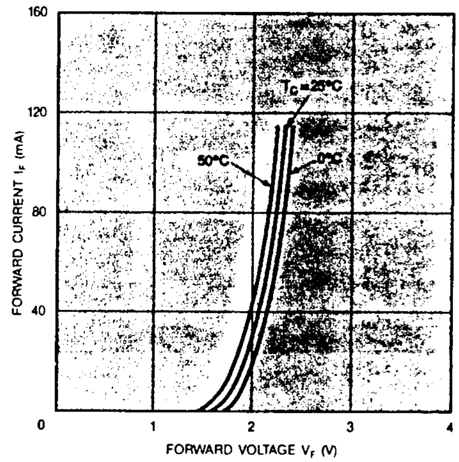
Optical Output Power vs. Forward Current



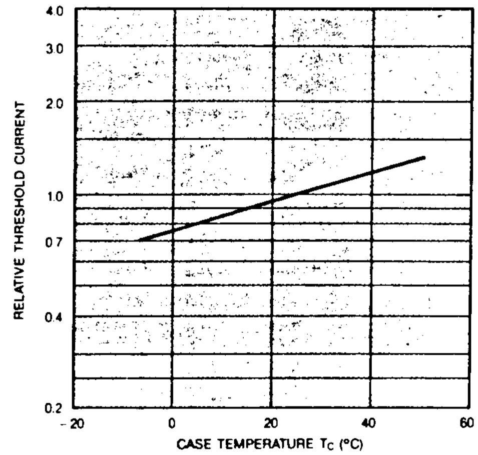
Monitor Current vs. Optical Output Power



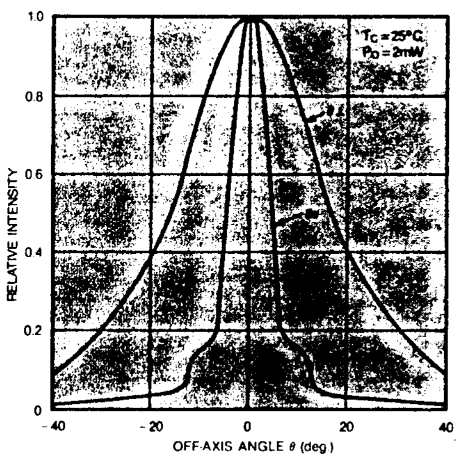
Forward Current vs. Forward Voltage



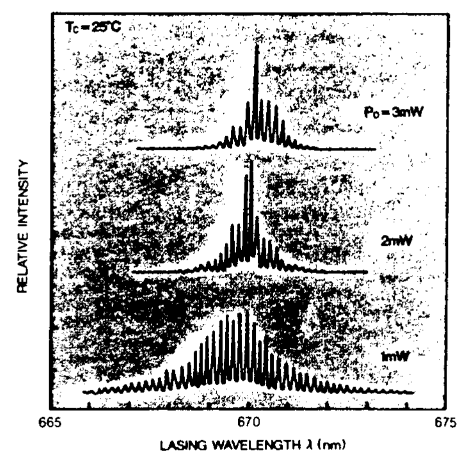
Case Temperature Dependence of Threshold Current



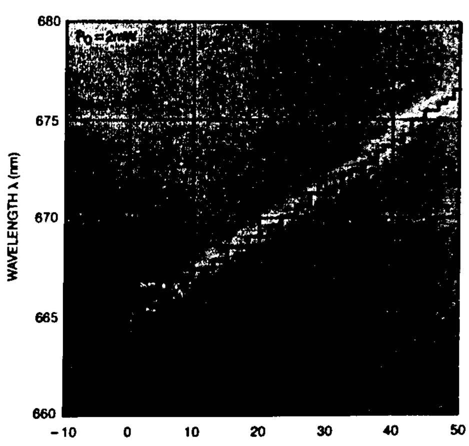
Far-Field Patterns



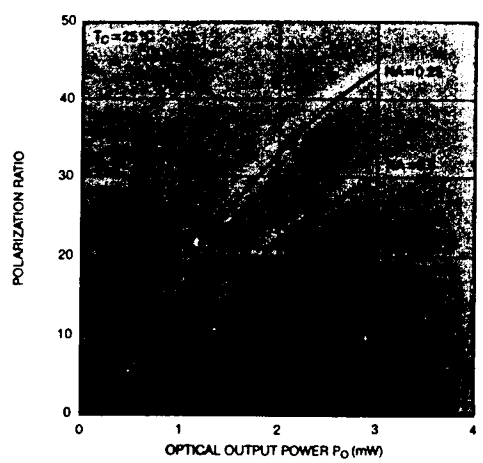
Lasing Spectrum



Case Temperature Dependence of Lasing Wavelength

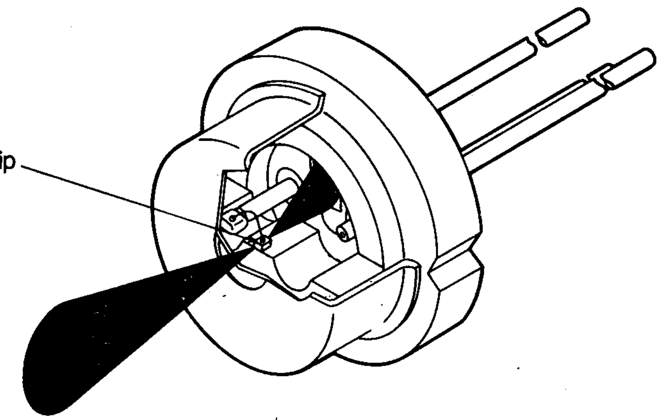


Polarization Ratio vs. Optical Output Power



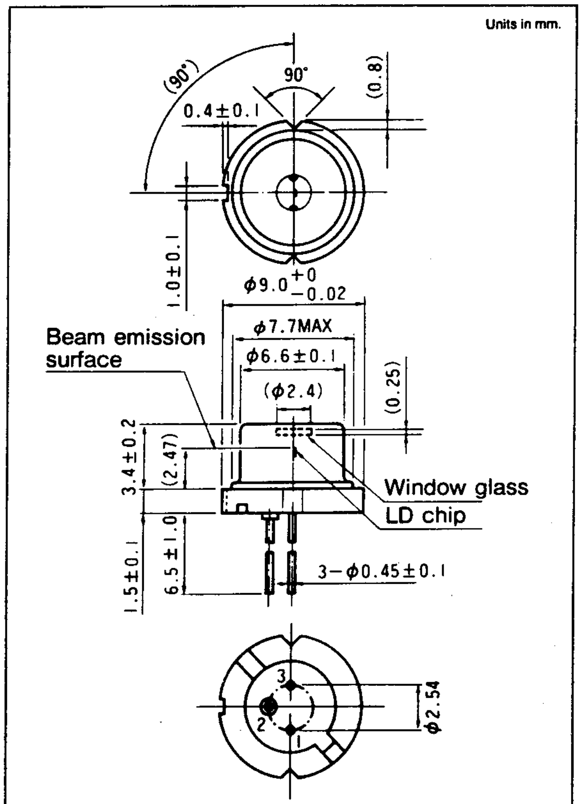
Package

Interior Diagram of VLD Package



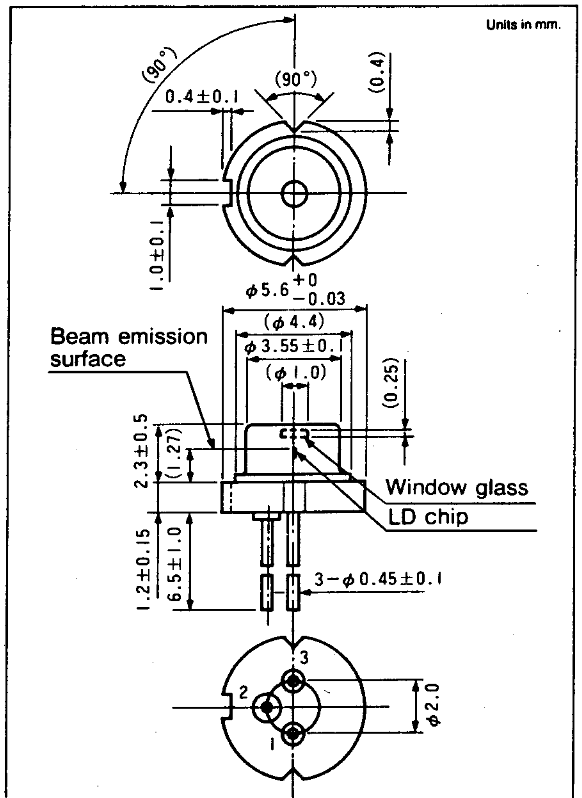
Dimensions of Package

Standard Package



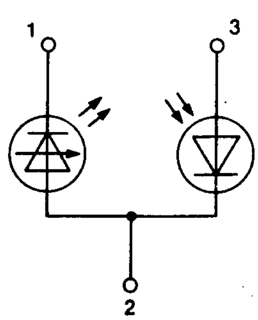
figures in parenthesis are typical values.

Small Package



figures in parenthesis are typical values.

Pin Connection



1. Laser diode cathode
2. Laser diode anode and photodiode cathode
3. Photodiode anode

※ *Case and pin no. 2 are in common.*

OL308A-75

MAS-TECH International, Inc.
29 Deer Run Drive
Randolph, New Jersey 07869
Tel: (201) 895-2200
Fax: (201) 895-4641

OKI OL308A-75 is 1.3μm InGaAs/InP high power laser diode developed as light source for fiber-optic communication system and optical instruments.

ABSOLUTE MAXIMUM RATINGS

(Ta=25°C)

Paramater	Symbol	Test Conditions	Rating	Unit
Optical Output		CW	75	mW
		Pulse *	100	mW
LD Foward Current	If (LD)	CW	400	mA
		Pulse *	600	mA
LD Reverse Voltage	Vr (LD)		2	V
PD Forward Current	If (PD)		10	mA
PD Reverse Voltage	Vr (PD)		15	V
Operating Temperature	Topr		-10 ~ +50	°C
Storage Temperature	Tstg		-40 ~ +100	°C

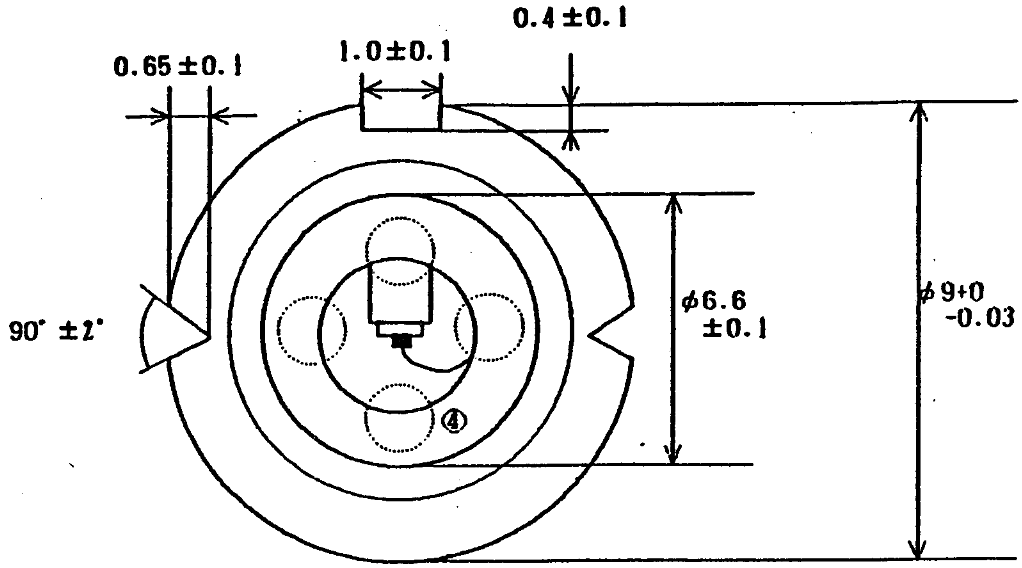
* Pulse Width ≤ 4μS, Duty ≤1%

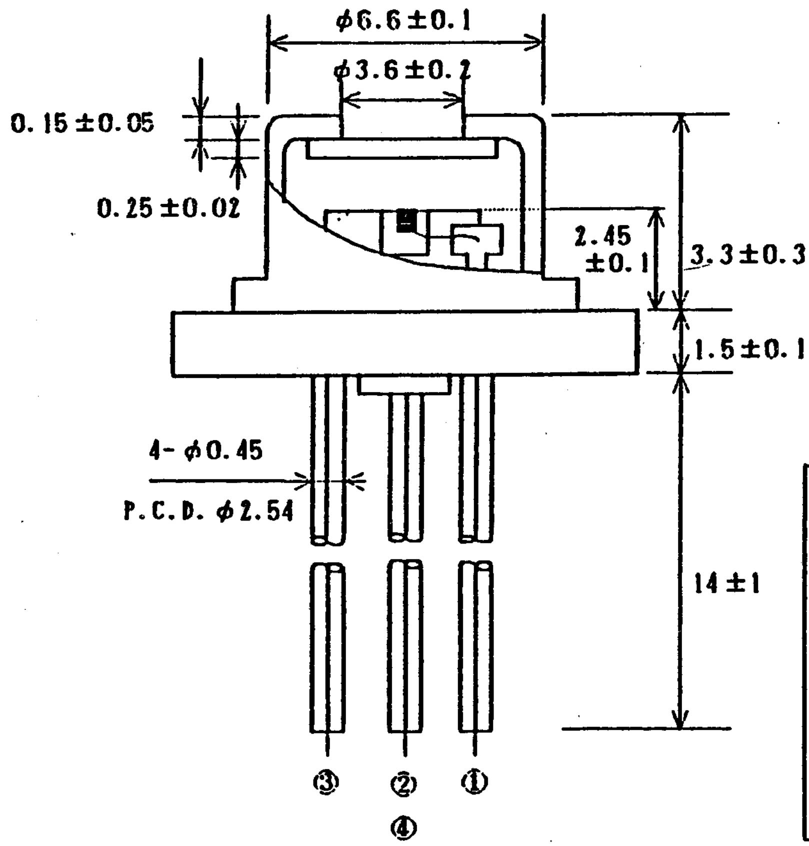
OPTICAL AND ELECTRICAL CHARACTERISTICS

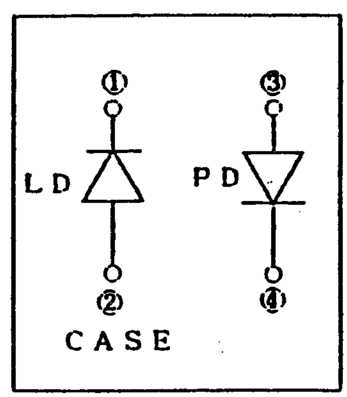
(Ta=25°C)

Parameter	Symbol	Test Condition	MIN	TYP	MAX	Unit
Thrshold Current	Ith	CW	-	50	70	mA
Operating Current	Iop	CW:Pop=75mW	-	350	400	mW
Forward Voltage	Vf	If=Ith + 30mA	-	1.1	1.5	V
Peak Wavelength	λp	CW:Pop=75mW	1270	1310	1330	ηm
Spectral Half Width	Δλ	CW:Pop=75mW	-	7	15	ηm
Monitor Current	Im	CW:Pop=75mW, Vrpd=5V	100	200	-	μA
Dark Current	Idark	Vr(PD)=5V	-	1	20	ηA
Full Angle at Half Maximum (parallel)	θ	CW:Pop=75mW	-	25	35	degree
Full Angle at Half Maximum (perpend)	θ	CW:Pop=75mW	-	30	40	degree

Package Dimensions (Unit:mm)







OKI OPTO ELECTRONIC DEVICES

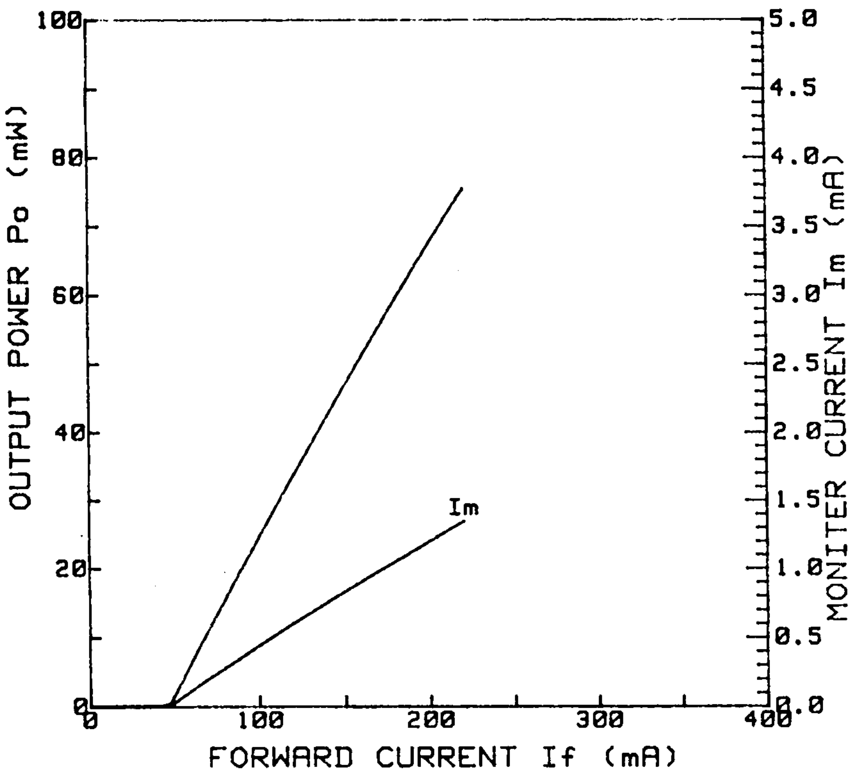
DATA SHEET

DATE 13/JUL/1992 TEMP = 25 °C

TYPE:OL308A-75 LOT NO:F3089MA S/N:1006

Ith = 46.9mA /Iop =220.0mA

Peak Wavelength	1297.0nm
Spectrum Width	6.4nm



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OKI OPTO ELECTRONIC DEVICES

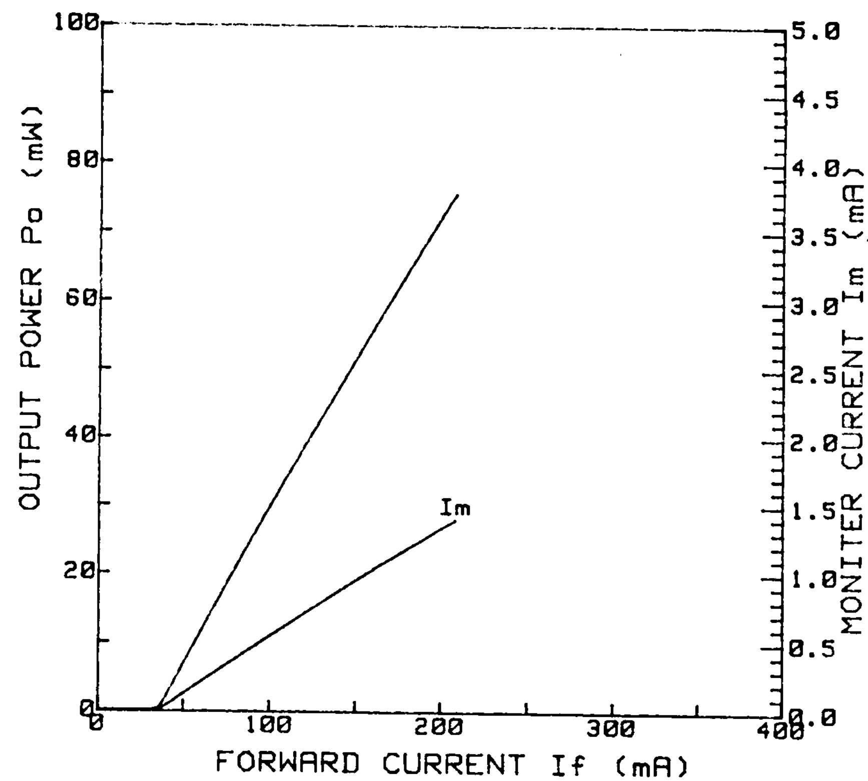
DATA SHEET

DATE 13/JUL/1992 TEMP = 25 °C

TYPE:OL308A-75 LOT NO:F3089MA S/N:1004

Ith = 35.0mA /Iop =208.0mA

Peak Wavelength	1300.6nm
Spectrum Width	3.7nm



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OKI OPTO ELECTRONIC DEVICES

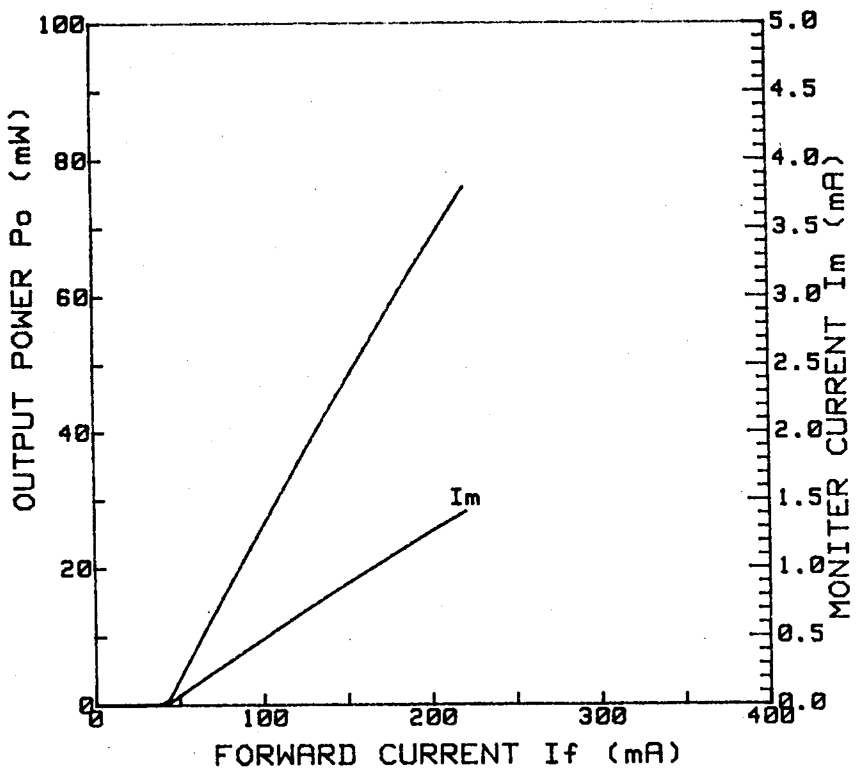
DATA SHEET

DATE 13/JUL/1992 TEMP = 25 °C

TYPE:OL308A-75 LOT NO:F3089MA S/N:1005

Ith = 42.1mA/Iop =220.0mA

Peak Wavelength 1299.0nm
Spectrum Width 5.8nm



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OKI OPTO ELECTRONIC DEVICES

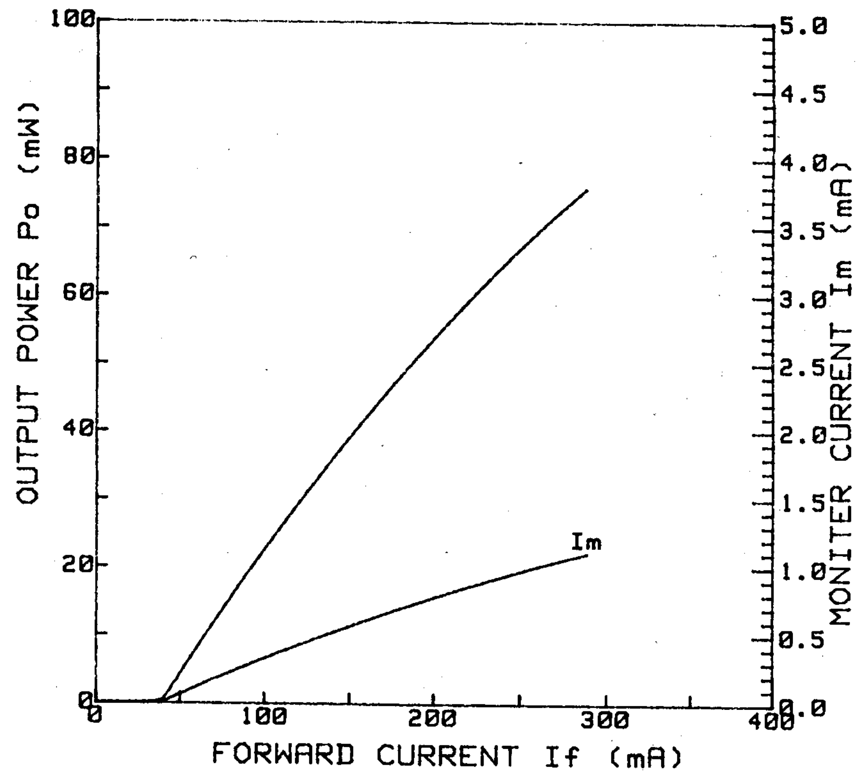
DATA SHEET

DATE 13/JUL/1992 TEMP = 25 °C

TYPE:OL308A-75 LOT NO:F3089MA S/N:1010

Ith = 38.6mA/Iop =288.0mA

Peak Wavelength 1293.6nm
Spectrum Width 7.3nm



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